Spectral Wave Decay Due To Bottom Friction On The Inner Shelf

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LONG-TERM GOALS

Long term goals are to observe and model wave and current boundary layer processes to determine to wave dissipation and wave-bed interactions in coastal and nearshore regions using novel instrumentation techniques.

SCIENTIFIC OBJECTIVES

The primary scientific objective of this project is to measure the bottom dissipation of surface gravity waves as they shoal across the continental shelf. Detailed observations of the bottom boundary layer, resolving the thin oscillatory wave boundary layer, are being made at two sites with differing wave forcing, mean currents and sediment bed types, to develop a spectral wave dissipation model for the continental shelf. At each site, continuous maps of the small scale morphology are being made in an area surrounding the detailed bottom boundary layer measurements to study changes in the bed in response to wave forcing, and to relate the effects of these morphology changes on the turbulence in the BBL. The spectral dissipation model will include the potentially strong influence of a wave-forced mobile bed, and parameterizations for low frequency currents including strong baroclinic tidal currents.

APPROACH

The SandyDuck experiment in September and October 1997 provided an opportunity to develop BBL dissipation techniques using prototype BBL instruments mounted on a mobile sled deployed offshore from a barred beach at Duck NC. Measurements made in 2-3m of water offshore of the barred beach under moderate forcing conditions are comparable to near-bed conditions further off shore under higher wave conditions.

During 1999, two long term inner shelf observation sites have been established to measure wave and current forcing and detailed measurements of BBL - bed responses. The Monterey Inner Shelf Observatory (MISO, Stanton 1999a) has an instrument frame at 12m depth in the southern end of

Monterey Bay at a site with .15mm mean diameter sandy bed and moderate, primarily narrow band, long period swell forcing conditions. A second site was established in 11m of water offshore from the Duck pier on 28 September 1999 and will be maintained through the end of the main SHOWEX field program in December 1999. The Duck site has significantly finer sediment and forcing is generally shorter period, but frequently energetic, in comparison with the Monterey site.

At each field site, dissipation in the bottom boundary layer are measured with O(1cm) resolution, three component Bistatic Coherent Doppler Velocimeter (BCDV) instruments (Stanton 1996, 1999b), which measure vertical profiles of velocity and sediment concentration over a 60 cm range above the bed at a 20Hz rate. These small-scale measurements of the bottom boundary layer are extended through the water column with high speed Broad Band Acoustic Doppler Profilers. Wave dissipation rates in the mean current and wave-forced bottom boundary layer are being estimated by decomposing mean, wave, and turbulent components of the three component velocity vector profiles to estimate the wave work term dissipating wave energy in the BBL. The co-located measurements of the velocity vector profiles and sediment concentration allow the sediment buoyancy terms in the TKE balance in the bottom boundary to be estimated when sediment suspension is occurring. As the local sediment morphology can greatly influence the characteristics of the bottom boundary layer (eg. Faria *et al* 1998), a two axis scanning sonar altimeter has been developed to quantitatively measure finescale morphology over a 4 by 2 m area centered on the BCDV profile measurements with 4 cm horizontal and 0.5 cm vertical resolutions. These local morphology maps are extended by qualitative 2D side-scan morphology images out to a 10m radius around the instrument frame. Periodic cross-shelf side-scan swaths of the bed are being measured in collaboration with Tom Herber's group to estimate mobile bed changes during storms. The BBL dissipation model will be tested against *in situ* cross shelf directional wave buoy observations being made by Herbers and O'Rielly at the SHOWEX site.

WORK COMPLETED

Analysis of data from prototype versions of the BCDV and scanning altimeter used during SandyDuck has allowed the development of techniques for estimating Reynolds stresses and dissipation rate profiles across the thin oscillatory boundary layer above a sloping bed. Part of this work has been accomplished with modeling contributions from NICOP collaborators Paolo Blondeux and Geovana Vittori.

Direct Numerical Simulations of a randomly forced oscillatory bottom boundary layer made by Donn Slinn are being used to explore how the finite sample volume, vertical profiles of velocity made by the BCDV can be best used to measure the wave dissipation rates. High resolution model output from a flat bottom run have been "sampled" using the acoustic response of the BCDV to define what part of the stress and strain field is resolved by the instrument, and importantly, what processes contributing to dissipation are not resolved. These analyses will be repeated when model runs with bedforms and bottom roughness are run to represent more closely the oscillatory velocity fields observed above sandy beds.

The need for increased vertical resolution and more three-component velocity profile bins was recognized in the prototype BCDV, and a significantly redesigned version of the instrument was implemented this year. The BCDV2 noninvasively measures (u,v,w) vectors and backscatter intensity every 0.6 cm in the vertical over a 60 cm range above the bed at 20 Hz. This represented a significant hardware and software development as the underwater package now contains 4 floating point Digital

Signal Processes (DSP'S) to pre-process the doppler information and reduce the still substantial data transmission and recording requirements. This new high resolution profiler is currently deployed at the Duck SHOWEX site.

Improvements were also made in the scanned acoustic altimeters used at both sites to measure the ripple field near the BCDV profiles allowing different sampling patterns to be used to capture rapidly changing bedforms. Given the long term, remote nature of the instrument deployment at the Duck site, a substantial effort was made to allow the BCDV2 to be moved remotely vertically and horizontally by 50 cm to accommodate large mean profile changes previously found at that site. The cross-shore movement allows the profiler to measure turbulence profiles at different locations across bedforms to resolve, for example, the effects of vortex shedding from sand ripples. Data acquisition of the instrument system and data archiving are handled by a UNIX workstation at each site, and the software allows remote programming and control of the instrument systems.

RESULTS

Analysis of the scanning altimeter and BCDV observations at SandyDuck, the MISO array, and more recently the SHOWEX Duck data and have shown that both instruments performed well, even in the strong wave forcing conditions experienced during storms. A patent application and manuscript describing the BCDV have been submitted (Stanton 1999c, 1999b).

The prototype BCDV1 resolved the bottom boundary layer adequately during the SandyDuck measurements, and it has allowed us to develop techniques for estimating turbulent Reynolds stresses without wave/slope contributions. In a collaborative work with Palo Blondeaux, <w~u~> correlations that arise from a sloping bed and reflected wave energy (Blondeaux et al 1999) have been modelled. Techniques to estimate the wave boundary layer dissipation rates from vertical strain measurements have been presented (Stanton and Thornton 1999), and a manuscript describing this method is being prepared.

Early results from the SHOWEX deployment at Duck, NC show the role of low frequency shelf currents in modifying bed roughness and the BBL. A 150 minute timeseries of an increasing current event measured 4m above the bed with the BADCP mounted on the 11m depth instrument frame is shown in Figure 1. The current increase was associated with an internal tidal bore propagating onshore with strong internal shear. Significant wave height at this time was 1.4m with short period, 6 second swells. A 50 second sample of the near-bed cross-shore velocity (Figure 2), taken near the end of the timeseries in Figure 1, is dominated by the swell orbital velocity, but with significant levels of high frequency turbulence superimposed. Near-bed turbulent dissipation rates (Figure 3) have been estimated from the vertical strain rate spectra, and are from 5 minute samples taken at the start and end of the current timeseries in Figure 1. The dissipation profile for the first sample (o symbols) shows a rapid increase in dissipation near the bed within the oscillatory boundary layer, with levels $<10^{-6}$ above approximately 10cm. In contrast, the dissipation rates measured two hours later (o), during the strong, baroclinic current pulses, are significantly higher above the oscillatory boundary layer. The effects of strong, low frequency currents on the BBL are currently being analysed.

IMPACT / APPLICATIONS

Observations of cross-shelf wave shoaling and energy loss under low wind conditions across the continental shelf (for example Hendrickson 1996) suggest that bottom dissipation is a zero'th order term in the cross-shelf wave evolution. Modelling of bottom dissipation in coastal regions will directly improve shelf wave models, which have wide ranging navy and civilian applications.

RELATED PROJECTS

This research has benefited from and contributed to the ONR-sponsored SandyDuck program in the development and deployment of the scanning X/Y altimeter and BCDV, which address overlapping issues in both programs.

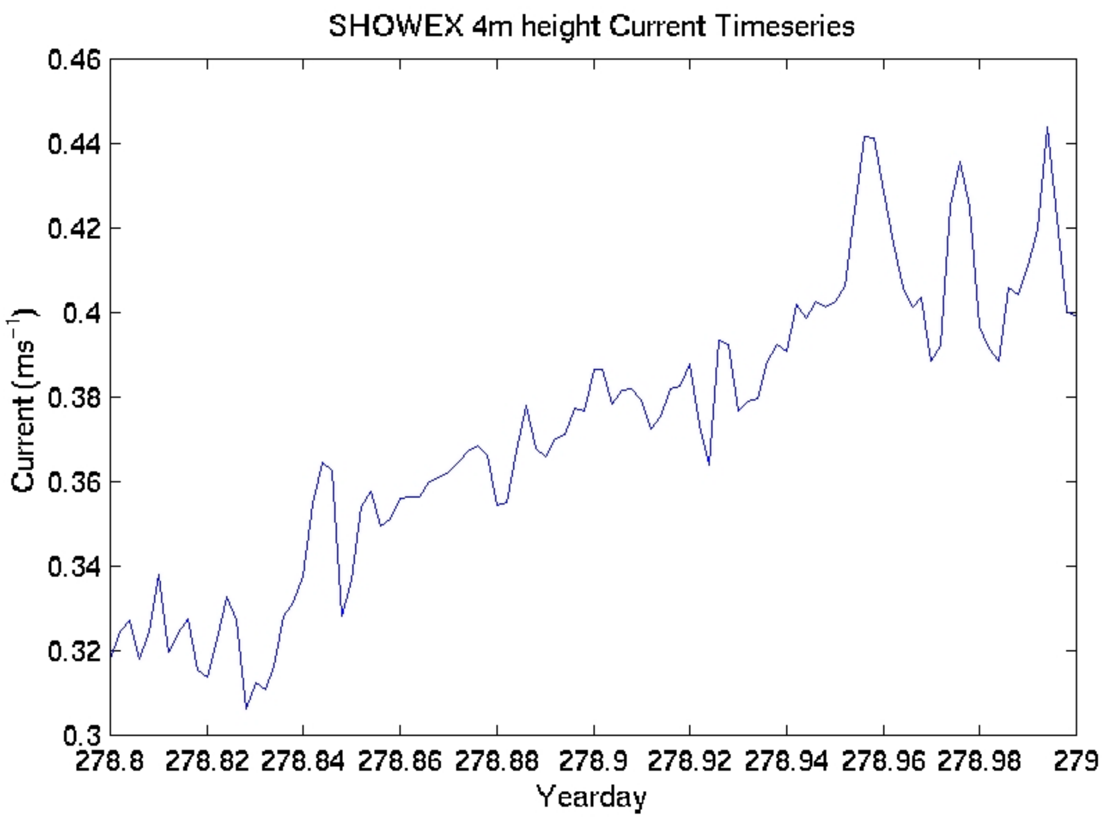

Figure 1. A 150 minute timeseries of current measured 4m above the bed in 11m of water, offshore from the FRF facility at Duck, NC during SHOWEX. The increasing current and pulses are the result of an internal tidal bore propagating onshore.

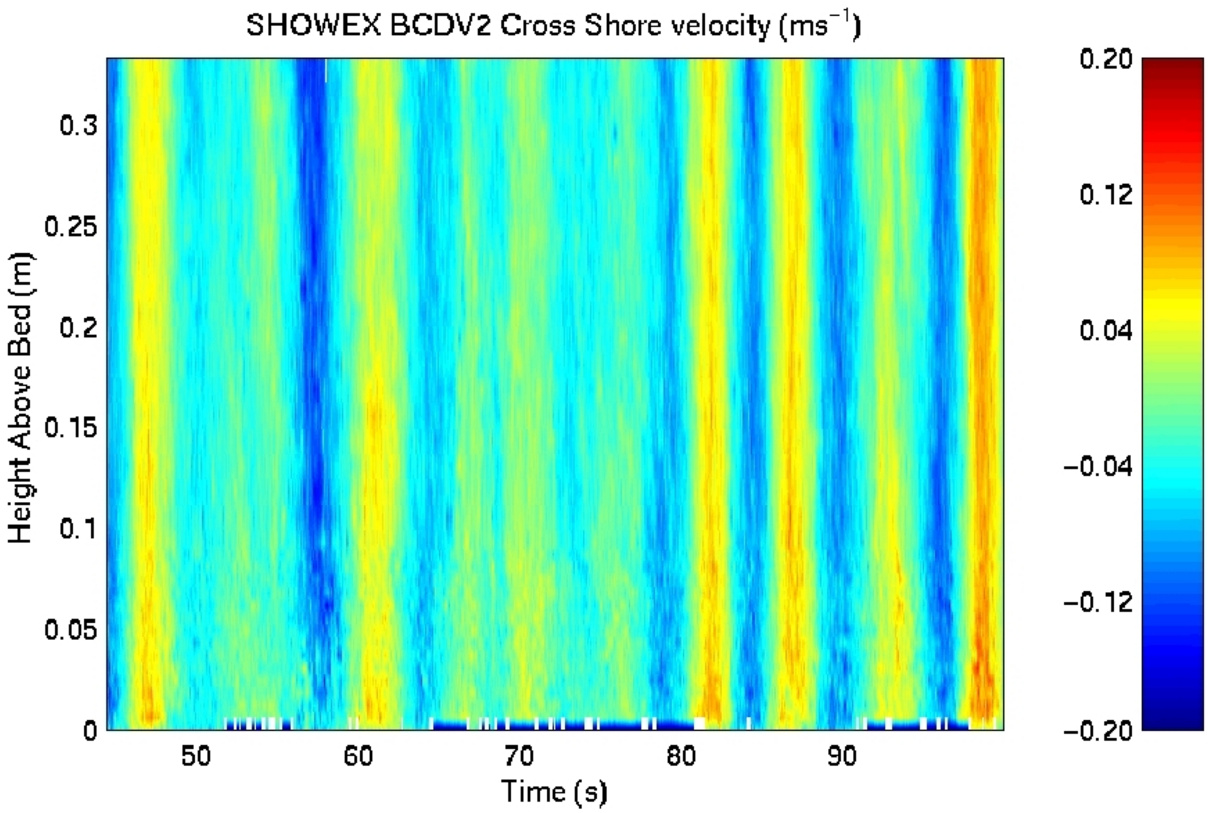

Figure 2. A 50 second profile timeseries of the cross-shore current component taken near the end of the timeseries in Figure 1. The near-bed current field is dominated by the swell orbital velocities with significant levels of turbulence superimposed.

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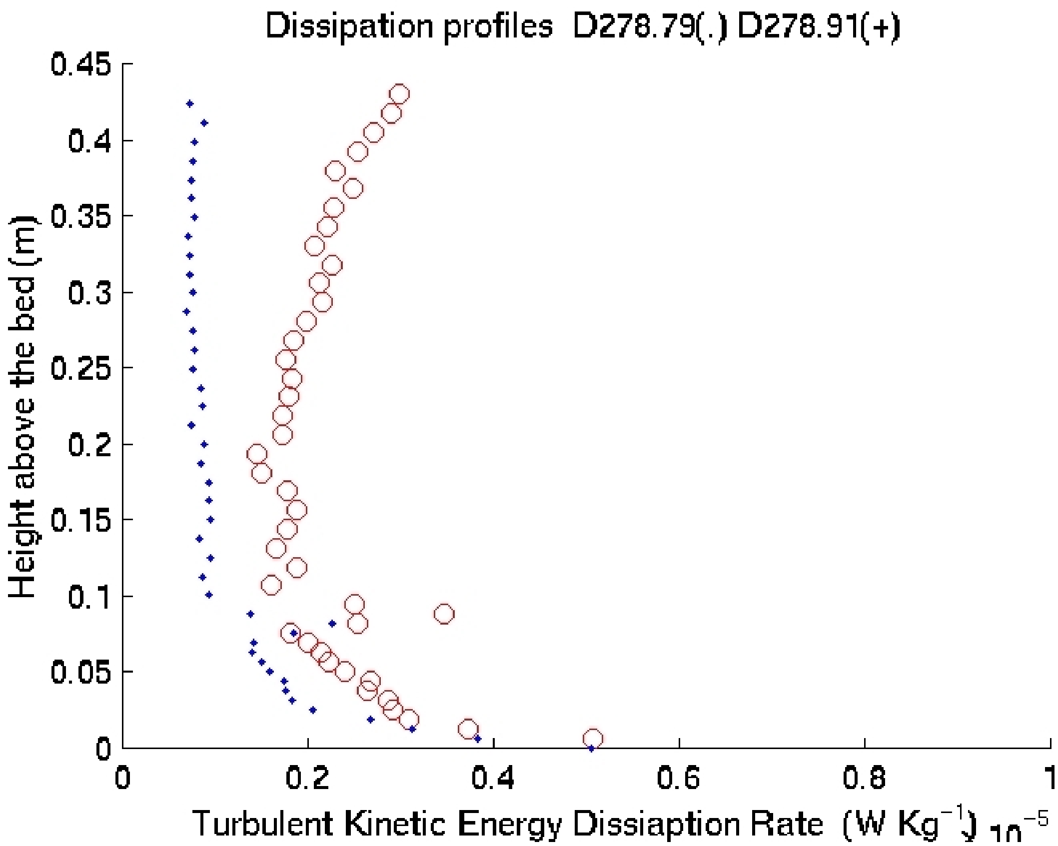

Figure 3. Turbulent kinetic energy dissipation rate profiles estimated over a 0.45 m height above the bed based on the vertical strain rate component. The first profile (. symbols) was measured near the start of the timeseries in Figure 1, and the second profile (o symbols) was sampled during strong current pulses seen later in the timeseries in Figure 1.

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PUBLICATIONS

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